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SEWAGE AERATION PRACTICE IN THE
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SEWAGE AERATION PRACTICE IN THE SANITARY DISTRICT OF CHICAGO

* Norval E. Anderson, M. ASCE

INTRODUCTION

Complete treatment is required for the sewage of The Sanitary District of Chicago, which now averages about 1,130 mgd, and is derived from a human population of 4,500,000 plus an industrial equivalent of 2,800,000, making a total equivalent population of about 7,300,000.

Complete treatment is required because the effluent and other drainage is taken by the Chicago Sanitary and Ship Canal (the Chicago River reversed) down the Illinois Waterway. Dilution in this waterway is limited by the decree of the United States Supreme Court, issued April 21, 1930, which provided that the annual average diversion from Lake Michigan into the Illinois Waterway at Chicago should be reduced from 8500 to 1500 cu ft per sec by December 31, 1938.

Actually, the 1500 cu ft per sec diversion authorized does not provide adequate dilution for nominal complete treatment of 90 to 95 per cent. The Sanitary District's continued pleas for an increase in diversion have been unsuccessful so far. Pearse⁽¹⁾ has summarized the 1940-41 testimony before the Supreme Court on this question.

The activated sludge process was selected by the Sanitary District for its major sewage treatment plants, as being the most economical for the degree of treatment required. Each plant was studied separately in this respect at the time of its planning. These studies were based on economic factors of the individual sites applied to data obtained from the Sanitary District's earlier treatment plants and experimental installations.

MAJOR ACTIVATED SLUDGE PLANTS

Physical Data

Physical data on the three major activated sludge plants of the Sanitary District are given in Table 1. The relatively large size of the plants, 136 mgd, 250 mgd, and 900 mgd, totalling 1286 mgd average capacity, resulted from economic considerations of the relative costs of intercepting sewers, pumping stations, and treatment works, applied to the topography of the area.

A brief discussion of the design of each plant, including explanation of the variations in some of the tabular data, follows.

North Side Sewage Treatment Works

The design of the original North Side Sewage Treatment Works was adopted on the recommendation of a commission of consulting engineers, consisting of Harrison P. Eddy, George W. Fuller, and T. Chalkley Hatton, after an exhaustive study of data and preliminary designs prepared by the Sanitary

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Table 1
PHYSICAL CHARACTERISTICS OF MAJOR ACTIVATED SLUDGE PLANTS
OF THE SANITARY DISTRICT OF CHICAGO

| | SEWAGE TREATMENT WORKS | | |
|--|------------------------------------|------------|-------------------------------------|
| | NORTH SIDE | CALUMET | WEST-SOUTHWEST |
| Operation started | 1928 | 1935 | 1939 |
| Alterations or additions completed | 1937 | 1951 | 1945 and 1949 |
| Designed capacity, mgd average | 250 | 136 | 900 |
| Sewage treated 1952, mgd average | 223 | 88 | 802 |
| Population 1950: Tributary, human | 1,080,000 | 440,000 | 2,820,000 |
| Treated, human plus indust. equiv. | 1,049,000 | 416,700 | 5,856,000 |
| PRELIMINARY TREATMENT: | | | |
| Grit chambers, velocity, ft per sec | 0.75-1.0 | none | none |
| Bar screens, clear openings, in | 3/4 | 5/8 | 2 |
| Settling tanks, aver. detention, min | 23 | 20 | 34(a) |
| AERATION TANKS: | | | |
| Detention, design, sewage basis, hr | 5.25 | 6.25 | 4.0 |
| Number of tanks (all spiral flow) | 36 | 21 | 24 |
| Width of flow channel, ft | 16.17(b) | 33.25(c) | 32.75 |
| Length of flow channel, ft | 420 | 425 | 1736 |
| Water depth, ft | 15.5 | 15.5 | 15.5 |
| Water depth over diffusers, ft | 15.0 | 15.0 | 15.0 |
| Top baffles, overhang, ft | 3.25 | 3.17 | 3.13 |
| Top baffles, angle from horiz. | 38°-10' | 40°-8' | 40°-30' |
| AERATION TANK DIFFUSER SYSTEM: | | | |
| Diffusers, 12x12" plates, per tank | 1440 | 720 | 16 - 2820(d) 8 - 4728 |
| Ratio, diffusers per sq ft tank area | 1:9.5 | 1:19.6 | 16 - 1:20(d) 8 - 1:12 |
| Width of diffusion band, ft | 3.75 | 3.54 | 16 - 3.00(d) 8 - 6.21 |
| Center of band to face of wall, ft | 3.44 | 3.60 | 16 - 3.08(d) 8 - 5.09 |
| FINAL SETTLING TANKS: | | | |
| Number of tanks and type mechanism | 42 Dorr | 16 Dorr | 72 Dorr |
| Size of tanks, ft | 30 - 77x77 12 - 75 dia | 91x91 | 126 dia. |
| Side water depth, ft | 30 - 13.0 12 - 12.0 | 12.0 | 32 - 11.0 40 - 13.75 |
| Influent arrangement | 30 - two opp. sides 12 - center | center | center |
| Effluent weir arrangement | 30 - grid 12 - peripheral | peripheral | 32 - peripheral 40 - an. troughs |
| Weir rate, design, gal/ft/day | 16,000(e) | 26,000 | 24,400(f) |
| Overflow rate, design, gal/sq ft/day | 960 | 1040 | 1000 |
| Sludge draw-off at | center | center | center |

(a) 34 min for Southwest sewage at 400 mgd. West Side sewage receives about 1 1/2 hr settling in Imhoff tanks.

(b) One tank has 33.5-ft channel. (c) One tank has 67.5-ft channel.

(d) Additional variations in tanks of Battery A due to experimental diffuser arrangements still in use?

(e) 30 tanks at 14,500; 12 tanks at 22,500 gal per ft per day.

(f) 32 tanks at 32,500; 40 tanks at 20,000 gal per ft per day.

District. The commission reported February 27, 1922, the first contract was awarded in August 1923, and the plant went into operation in October 1928, with a design capacity of 175 mgd.

The aeration plant is divided into three batteries of aeration and final settling tanks with an operating gallery between the aeration and final tanks of each battery.

There are 12 aeration tanks, 32 by 420 ft in each battery. Each tank has a dividing wall, making two parallel 16-ft flow channels, except for one tank with a full 33-ft channel. The aeration tanks have remained unchanged.

Originally there were 10 final settling tanks in each battery, each 77 ft square, equipped with Dorr mechanisms with extension arms to sweep the corner areas. The influent is introduced over weirs on two opposite sides of the tanks and the effluent is taken off by a grid of weir troughs suspended in the tank. These tanks are still in service. In 1937, four additional final settling tanks were added to each battery. The latter tanks are 75-ft diameter, center feed, with peripheral effluent weirs, and Dorr mechanisms.

The addition of the 12 final tanks increased the plant capacity from 175 to 250 mgd average flow. This was possible because the commission of consulting engineers previously mentioned had recommended six hours detention in the aeration tanks on the mixed liquor basis, but the hydraulics of the three batteries was designed for an average flow of 250 mgd in anticipation of the aeration tank design being too conservative.

Calumet Sewage Treatment Works

The aeration system of the Calumet plant has remained practically as designed, because the tributary flow has not yet reached the design capacity. In this plant, also, the hydraulic capacity was made 20 per cent greater than the nominal treatment capacity, in anticipation of the tank design being too conservative.

The aeration plant is divided into two batteries of aeration and final settling tanks with operating galleries between, similar in layout to the North Side plant. The aeration tanks are 33.25 ft by 425 ft, except that one tank is 66.5 ft wide, making 11 tanks in one battery and 10 in the other. All tanks are single pass, with the flow channel the same width as the tanks.

There are eight final settling tanks in each battery, each 91 ft square, equipped with Dorr mechanisms with extension arms which sweep the corner areas. The influent is through the center pier and effluent over peripheral weirs.

The plant additions in 1950-51 consisted of four preliminary settling tanks, thereby increasing the original settling period from 10 to 20 minutes. Also, the 16th final tank was completed. This tank had been omitted from the original construction for the purpose of trying out a multiple-tray type tank in its place. The tray-tank idea was abandoned before it was built. At the same time the final tank mechanisms were converted from traction drive to center drive.

West-Southwest Sewage Treatment Works

The original aeration plant of the West-Southwest Sewage Treatment Works was designed for 400 mgd of Southwest sewage and consisted of two batteries (A and B), each battery having eight aeration tanks, 16 final settling tanks, with an operating gallery between.

The aeration tanks are 136 ft by 434 ft, divided into four passes, making the flow channels 33.25 ft wide and 1736 ft long, with both influent and effluent at the same end.

The original 32 final settling tanks - 16 per battery - are 126 ft in diameter, center feed, peripheral effluent weirs, and equipped with 4-arm center-drive Dorr mechanisms.

In 1945, 16 final tanks - 8 per battery - were added to the original two batteries of tanks, and the rated capacity increased to 500 mgd. These added tanks differ from the original in that the mechanisms have two arms in place of four, and the effluent weirs are on the two sides of a 4-ft concrete trough cantilevered in 14-ft from the tank wall.

In 1949, a third battery was added to the plant and the rated capacity raised to 900 mgd. Battery C is similar in layout to A and B, with eight aeration tanks of the same dimensions, and 24 final tanks practically the same as the 1945 additions to A and B.

The 1949 addition also provided for bringing the West Side Imhoff tank of effluent into the aeration plant for final treatment. The West Side sewage, roughly 60 per cent of the 900 mgd total, receives an average of 1.35 hrs settling while the Southwest sewage would be retained only 35 minutes in the preliminary tanks, making the average of 63 minutes preliminary settling for the mixed West-Southwest sewage at design flow.

The following tabulation gives the major design factors for the successive changes in the West-Southwest aeration plant.

| DESIGN FACTORS AT AVERAGE DESIGN FLOW | ORIGINAL 1939 | WITH ADDITION 1945 | WITH ADDITION 1949 |
|---|------------------|--------------------------|--------------------------|
| Design flow, average, mgd | 400 | 500 | 900 |
| Aeration tanks: | | | |
| Number of tanks (136 x 434 ft) | 16 | 16 | 24 |
| Detention, sewage bases, hr | 6.0 | 4.8 | 4.0 |
| Sludge return, per cent | 20 | 30 | 30 |
| Detention, mixed liquor basis, hr | 5.0 | 3.7 | 3.1 |
| Diffuser ratio, plates to sq ft tank: | | | |
| Batteries A and B | 1 to 20 | 1 to 20 * | 1 to 20 * |
| Battery C | | | 1 to 12 |
| Final Settling tanks: | | | |
| Number of tanks (126 ft dia.) | 32 | 48 | 72 |
| Side water depth, ft: Original | 11.0 | 11.0 | 11.0 |
| Added tanks | | 13.75 | 13.75 |
| Effluent weirs per tank, ft: Original | 381 | 381 | 381 |
| Added tanks | | 615 | 615 |
| Detention, mixed liquor basis, hr | 2.0 | 2.2 | 1.9 |
| Overflow rate, gal per sq ft per day | 1000 | 833 | 1000 |
| Weir rate, gal per ft per day: | | | |
| Original | 32,800 | 27,300 | 32,800 |
| Added tanks | | 17,000 | 20,300 |

*Variations in tanks of Battery A due to experimental diffuser arrangements still in use.

MAJOR ACTIVATED SLUDGE PLANTS

Operating Data

Average operating results for the aeration process of the three major plants are given in Table 2. The data for recent representative periods have

Table 2

AVERAGE OPERATING DATA OF MAJOR ACTIVATED SLUDGE PLANTS OF THE SANITARY DISTRICT OF CHICAGO

| | SEWAGE TREATMENT WORKS | | |
|--|------------------------|---------|--------------------|
| | NORTH SIDE | CALUMET | WEST- SOUTHWEST |
| Years covered by average data, inclusive | 1946-50 | 1946-50 | 1951-52 |
| Sewage treated, mgd | 213 | 77 | 794 |
| Raw sewage: Suspended solids, ppm | 135 | 146 | 185 |
| 5-day B.O.D., ppm | 102 | 109 | 143 |
| Preliminary settling: Detention, min | 27 | 18 | 71(a) |
| Suspended solids removed, per cent | 35 | 28 | 43 |
| 5-day B.O.D. removed, per cent | 25 | 20 | 32 |
| Aeration period: Sewage basis, hr | 6.0 | 6.1 | 4.6 |
| Total flow basis, hr | 4.9 | 4.9 | 3.3 |
| Sludge return, per cent | 22.7 | 24.4 | 38.5 |
| Mixed liquor: Suspended solids, ppm | 2000 | 2230 | 2330 |
| Solids aeration period, hr | 152 | 150 | 118 |
| Sludge age (Gould), days | 5.7 | 5.4 | 4.2 |
| B.O.D. loading, lb/1000 cu ft aeration tank vol. | 19 | 19 | 32 |
| Air used: cu ft per gal of sewage | 0.48 | 0.48 | 0.68 |
| Cu ft/lb 5-day B.O.D. removed: Raw sewage | 600 | 590 | 600 |
| Settled sewage | 800 | 740 | 905 |
| Final settling: | | | |
| Detention period, hr | 2.1(b) | 2.3 | 2.1(c) |
| Overflow rate, gal per sq ft per day | 925 | 810 | 885 |
| Weir rate, gal per ft of weir per day | 13,500(d) | 18,700 | 21,600(e) |
| Solids rate (mixed liquor solids settled from overflow), lb per sq ft per day | 15.4 | 15.7 | 17.2 |
| Sludge index (Mohlman) | 89 | 58 | 81 |
| Sludge index (Donaldson) | 1.12 | 1.72 | 1.23 |
| Final effluent: Suspended solids, ppm | 9 | 14 | 15 |
| 5-day B.O.D., ppm | 6 | 11 | 7 |
| Removal from preliminary effluent: | | | |
| Suspended solids, per cent | 88.5 | 87.0 | 86.0 |
| 5-day B.O.D., per cent | 92.5 | 87.5 | 92.0 |
| Removal from raw sewage: | | | |
| Suspended solids, per cent | 93.5 | 91.8 | 92.0 |
| 5-day B.O.D., per cent | 94.0 | 90.0 | 94.7 |

(a) 468 mgd in West Side Imhoff tanks at 93 min, and 326 mgd in Southwest preliminary tanks at 39 min, averages 71 min.

(b) 30 final tanks at 2.7 hr, 12 at 1.8 hr, averages 2.6 hr.

(c) 32 final tanks at 1.9 hr, 16 at 2.2 hr, and 24 at 2.4 hr, averages 2.1 hr.

(d) 30 final tanks at 12,400, and 12 at 19,200, averages 13,500 gal/ft/day.

(e) 40 final tanks at 17,900, and 32 at 28,900, averages 21,600 gal/ft/day.

been given in each case: 1946-1950, inclusive, for North Side because of irregular operation in 1951 while installing new diffusers; 1946-1950, inclusive, for Calumet because of irregular operations in 1951 while installing additional preliminary tanks; 1951 and 1952 for West-Southwest since the third battery of tanks has been in operation.

Some of the factors given in the tabulation are not ordinarily reported in operating results because they are not of direct concern to the operator. However, they may have significance for the designer, and are defined as follows:

Sludge age (used by Gould), given in days, is the pounds of mixed liquor suspended solids in the aeration tanks divided by the pounds of suspended solids added to the aeration system per day.

Solids aeration period (used in S.D.C. studies), given in hours, is the pounds of mixed liquor suspended solids in the aeration tanks divided by the pounds of suspended solids removed from the sewage per hour.

The above are similar and useful indices for the designer and, also, for the operator as a general guide to the proper quantity of mixed liquor solids to be carried in the system. However, the District does not use either in routine operation control.

Solids rate, for final settling tanks, in lb per sq ft per day, is the quantity of mixed liquor suspended solids settled from the final tank overflow. This is an additional criterion for final tank design, suggested by H. R. King, of the Sanitary District, which we believe has an important influence on settling tank performance.

Operating results are, of course, affected by the type of sewage treated, as well as by the design characteristics of the treatment works. Even for three large plants in the same metropolitan area, the sewages are different.

North Side sewage is predominantly domestic, relatively weak - about 102 ppm B.O.D., and yields readily to treatment.

Calumet sewage is a little more concentrated - about 109 ppm B.O.D.; and, although largely domestic, contains a considerable amount of troublesome industrial wastes, such as pickling liquor which adds an average of about 7 ppm Fe, paint wastes which sometimes give unusual color effects, and oily wastes.

West-Southwest sewage is the strongest - about 143 ppm B.O.D.; and has the highest percentage of industrial wastes, including those from the stockyards and the large meat-packing plants.

In general, operating results for the activated sludge plants of The Sanitary District of Chicago are very good, among the best reported. However, yearly average results always seem a bit disappointing to those responsible for the design and operation of the plants. After noting final effluent B.O.D.'s and suspended solids run 3 to 5 ppm for weeks, it is surprising that there are enough bad periods to bring the yearly averages up to 10 or 15 ppm.

BASES FOR DESIGN

The Sanitary District of Chicago is one of the pioneers in the activated sludge process, some of the earliest data being developed under the direction of Langdon Pearse, Sanitary Engineer, and Floyd W. Mohlman, Director of Laboratories. Experimental sewage testing stations were built and operated: at Thirty-Ninth Street Pumping Station, on domestic sewage, from 1908 to 1911; at the Stockyards, on packinghouse wastes, from 1912 to 1918; along the North Branch, on tannery wastes, from 1919 to 1922; at Argo, on Corn Products Refinery Company wastes, from 1920 to 1926; and at Sherwin-Williams

Paint Company Plant, from 1926 to 1928. The Des Plaines River Sewage Treatment Works,⁽²⁾ a 4.5 mgd activated sludge plant, was operated on a semi-experimental basis from 1922 to 1931. The old Calumet Sewage Treatment Works included two experimental activated sludge units⁽³⁾ of about 1.5 mgd capacity each, which were operated in various ways from 1923 to 1935. Also, each of the major plants have been operated on an experimental basis, in whole or in part, at various periods to test ideas or obtain specific data.

Design criteria for the Sanitary District's aeration plants have been obtained from such experiments, with due consideration of the experimental and operating data of other plants. The basis for the major design factors are summarized in the following.

Preliminary Treatment

Evaluation of the desirable degree of preliminary treatment has fluctuated from time to time, and has been influenced by its effect on ultimate sludge disposal as much as by consideration of economy in the aeration process.

In the original design of the North Side Works, mechanically cleaned fine screens with 1/16-in openings were contemplated in accordance with previous practice. However, before these were built, comparative studies showed that about 30 minutes preliminary settling would remove five or six times as much coarse solids at about the same or less cost; and this was adopted.

The Calumet Works were originally built with only 10 minutes preliminary settling because it was thought at the time that this would give the most advantageous sludge mixture for vacuum filtering and heat drying of waste sludge. Operating experience showed that more preliminary tank volume was desirable for flexibility in handling peak flows. In 1951 the preliminary settling tank capacity was doubled to give 20 min detention at design flow.

At the West-Southwest Works, preliminary settling of 34 min at 400 mgd is provided for Southwest sewage. The average preliminary settling of more than one hour for the West-Southwest Works results from the continued use of the Imhoff tanks for preliminary treatment of West Side sewage.

In considering the effect of preliminary treatment, it appears that air requirements are not reduced in proportion to the removal of suspended solids or B.O.D. prior to aeration. This is probably due to a slower rate of oxidation for the coarse solids removed in the preliminary process.

Aeration Tank Type and Proportions

Although spiral flow aeration tanks are almost universally used in this country, as opposed to the ridge and furrow type still favored to a considerable extent in Britain, it may be well to note why.

Plans for the North Side aeration tanks were changed from ridge and furrow to spiral flow just before construction, after tests at the Des Plaines River Plant demonstrated the superiority of the spiral flow type. The advantages of spiral flow are: greater air economy, lower construction cost, and more accessible location of diffusers for maintenance.

Numerous velocity traverses with current meters on the District's spiral-flow aeration tanks have failed to show any dead zone or core in the cross section, contrary to frequent theorizing on that condition. Therefore, the District has never used baffles nor cross aeration to break up the core.

For water depth of aeration tanks, the District has standardized on 15 feet above the diffusers, although a theoretical study by ⁽⁴⁾ Anderson, in 1934, indicated that different depths probably could be used with little if any loss in power economy if site conditions made shallower or deeper tanks advantageous.

An aeration channel width of approximately 33 feet has been used since it was demonstrated by comparative operating tests at the North Side Works that the one tank which was made 33.5 ft wide gave results equal to the 16-ft. channels of the other tanks. At the Calumet Works, one aeration tank was made 67.5 feet wide, but with two rows of air diffuser plates on each side of the tank; and apparently gives results equal to the 33-ft channels. Channel width does not appear to be critical and is selected to give the best layout of units. Wider channels, of course, give lower construction costs.

Aeration tank lengths, at least in the range required for large plants, do not appear to affect operating results and are selected to fit layout conditions. At the North Side and Calumet Works, aeration tanks are approximately 420 feet long with the influent at one end and the effluent at the other. At the West-Southwest Works, the aeration tanks are 434 feet long, but each tank is divided into 4 passes of 33.75-ft width so that the flow length of each tank is 1736 ft with the influent and effluent at the same end.

Baffles at the tops of aeration tank walls have been provided in all cases with an overhang of about 3.2 feet and an angle of about 40° from the horizontal. For Battery C of the West-Southwest Works, the baffles have a 3-ft radius fillet to the wall; all others are straight. Tests at the Des Plaines River Works in 1924 with baffles at 35° , 40° , 50° and 60° from the horizontal showed small differences in resulting velocities. Also, tests at the North Side Works in 1935 on 4-ft radius vs straight baffles showed little difference in velocity of circulation. For the past two years, we have been questioning the value of any baffles which increase circulating velocity, on the basis of overall oxygen absorption, because higher velocities decrease the bubble contact period, thereby reducing oxygen absorption from the bubbles which normally give several times more absorption than the surface aeration. Limited tests on a model-size tank seem to confirm this so far. This would not apply in the treatment of a weak sewage if the air requirements were not sufficient to maintain the minimum velocity to prevent settling without the aid of baffles.

Air Diffusers

The Sanitary District uses standard 12 by 12-in porous diffuser plates of 80 permeability in all its major plants. The decision to continue the use of plates in the latest design was based on comprehensive comparative tests started in 1941 and reported by Anderson⁽⁵⁾, in 1949. These tests were started at a time when the Sanitary District was about ready to abandon plate diffusers in favor of almost anything at the West-Southwest Works, because of a serious clogging problem. The major test was a comparison of the eight aeration tanks of Battery A at West-Southwest, each equipped with a different diffuser system, operated in parallel. The diffuser systems tested included plates of various permeabilities and arrangements, slotted brass tubes, fixed porous tubes, and porous tubes and "decision tubes" on "swing diffusers".

Economic studies, based on the test results, led to adoption of the diffuser design for Battery C, the 300 mgd addition to the West-Southwest Works completed in 1949. The salient features of the diffuser system are: a new air filtering system consisting of bag filters with loose asbestos fiber lining for primary filtering, followed by automatic electronic filters; diffuser plates of 80-permeability rating, cemented into 6-plate precast concrete holders; plate holders set normal to the tank wall and connected into 4-in headers 34 ft long, with a 6-in feeder at the center of each header; 4,728 plates per tank, making an average diffuser ratio of 1:12 and an average air rate of 3.0 cfm per plate; a 27 per cent greater concentration of plates in the influent half of the tank than in the effluent half, for the purpose of securing more uniform

clogging rate of the diffusers, and not for "tapered aeration".

Recent tests by King⁽⁶⁾, in measuring the oxygen absorption rating of diffusers, has given us a long-needed test of diffuser pore size to supplement the permeability specification in the purchase of diffusers.

Aeration Period

From a conservative 6.25-hr aeration period (mixed liquor basis), used in the original design of the North Side Works, in 1925, the period has been gradually reduced on the basis of experiments and operating data to the latest figure for the West-Southwest Works of 3.1 hr on the mixed liquor basis or 4.0 hr on a sewage-only basis. It should be kept in mind that this is for complete treatment without sludge reaeration.

A large scale experiment at the North Side Works, in which one battery of tanks were operated for two years (1934-1935) at an average aeration period of 3.0 to 3.5 hr (mixed liquor basis) without increased air per gal of sewage or sacrifice in quality of effluent, demonstrated that the shorter period could be used on North Side sewage.

A 0.6 mgd experimental plant⁽⁷⁾, operated in 1938, on West Side Imhoff tank effluent, gave 89 per cent overall removal of B.O.D. for raw sewage of 78 to 101 ppm, B.O.D., with aeration periods of 1.6 to 2.3 hr, sewage basis, using 0.18 to 0.26 cu ft of air per gal of sewage.

Air Use

Design estimates of air requirements for the various plants have not proved too accurate. For North Side Works, the design provided for an average of 0.8 cu ft of free air per gal of sewage, while the actual yearly averages have ranged from 0.35 to 0.68. Calumet was designed for 0.5 cu ft per gal, and the yearly averages range from 0.36 to 0.52. West-Southwest was designed for 0.55 cu ft per gal, and the yearly averages range from 0.58 to 0.69.

Sludge Return

The rate of sludge return is determined by the solids concentration to be carried in the mixed liquor and the settling characteristics of the sludge. The practice of the Sanitary District has been to allow a generous range of capacity after selecting a nominal percentage of average sewage flow for the sludge return. The following tabulation compares the design allowances with operating practice.

| | <u>Design Average</u> | <u>Design Range mgd</u> | <u>Range of Yearly Averages, mgd</u> |
|----------------|---------------------------|-----------------------------|--|
| North Side | 20% | 25-100 | 40-50 |
| Calumet | 20% | 15-55 | 16-24 |
| West-Southwest | 30% | 100-360 | 250-300 |

Air lifts, two 16-in for each final tank, are used for sludge return at West-Southwest. These have proved very desirable for flexibility and ease of control in addition to the savings in construction cost of a pumping station and conduits. Air lifts had been used on the early small plants and experimental installations, but centrifugal pumps are used at North Side and Calumet.

Final Settling Tanks

The latest final settling tank design of the Sanitary District is that for Battery C, the 300 mgd addition to the West-Southwest Works completed in 1949. These tanks are 126 ft diameter, 13.75 ft side water depth, 17.58 ft center depth, with influent up through the center pier, and sludge draw-off at the center bottom. The effluent weirs are on both sides of a 4-ft concrete

effluent trough placed concentrically in the tank 14 ft from the tank wall to the center of trough. The trough is carried on concrete cantilever brackets from the tank wall.

In addition to good operating characteristics, circular tanks are economical in construction cost. Alternate bids taken in 1941 on rectangular vs circular tanks resulted in the low bid for rectangular tanks being \$320,325.50, or 30 per cent higher than the low bid for circular tanks. In the design of these alternates (16 tanks for addition to Batteries A and B at West-Southwest), the tanks had the same volume, same minimum depth, and same effluent weir length.

The hydraulic design of the final settling tanks was adopted as a result of comprehensive tests started in 1940 and reported by Anderson⁽⁸⁾ in 1944. The tests included velocity measurements in final tanks at Cleveland, Columbus, and New York, as well as many trial installations in Chicago's Southwest Works. Also, the District had done a considerable amount of testing on rectangular tanks at the old Des Plaines River Works and at the North Side Works in 1931.

Some of the conclusions drawn from the test data were: tank depths should be not less than 10 ft, nor less than 12 ft if weirs are located near the upturn of the density current; no baffling arrangement of the influent had an appreciable effect on the effluent; the best influent improvement is low entrance velocity; effluent weirs should preferably be located away from the upturn of density current; the overflow rate for effluent weirs should not exceed about 20,000 gpd per ft of weir, nor 15,000 gpd per ft if weirs are located at the upturn of density current; the sludge draw-off should be near the influent.

Why Not Step-Aeration or Re-Aeration

Step-aeration or other form of re-aeration has not been adopted because studies of available data to date have indicated that, for the high degree of treatment required by the Sanitary District, there would be comparatively little saving in overall costs and a probable sacrifice in quality of effluent. However, an open mind is being kept on this method of operation. The possibility of converting to some form of re-aeration has been considered in case it were necessary to increase the capacity of a plant under conditions such that it were not feasible to increase tank capacities.

The potential economy of re-aeration, of course, would be the reduction in tank volume necessary to maintain the same period of sludge aeration, or sludge age, and the same sewage aeration period. However, this would be partially offset by more conduits and controls, by a more elaborate air diffusion system, and by an increase in operating costs for supplying more air. For best results with re-aeration, we believe that the rate of air supplied in the re-aeration step should be much higher than for a conventional aeration tank; and that, for a comparable effluent, the overall air requirement would be greater.

We doubt that an equal degree of treatment would be obtained because, with the reduction in tank volume necessary to show an economy for a sludge re-aeration process, the ratio of sludge return solids to sewage solids would be much lower, also, the contact period of sewage solids with the returned sludge would be shorter. We believe that these factors are important in producing a good effluent, but more data are necessary to properly evaluate them.

Experiments on sludge re-aeration were carried out by the Sanitary District at the Tannery testing station in 1920, and at the Des Plaines River Works from 1923 to 1931, with no apparent merit indicated. Better tests

were made at the North Side Works in 1934 and 1935 by A. J. Beck, when the necessity for a high rate of air supply to the return sludge began to be appreciated. Beck's conclusion from the latter test was that, "A saving in aeration tanks could be made by aeration of return sludge. However, more air would be required and the final effluent may be slightly poorer quality than with the present method of operation."

We believe there is need for more carefully controlled experimental work in this field of sludge re-aeration.

OPERATING CONTROL

Weekly plant control meetings at the West-Southwest Works have proved a valuable practice in maintaining good operation. The meetings, conducted by Dr. F. W. Mohlman, are attended by engineers and chemists representing the operating staff and engineers representing the design staff, with a total of 10 to 15 usually present. Operating results of the past week are discussed and operation planned for the week ahead. Also, it gives opportunity for informal discussion of problems and ideas between the operators and the designers.

All of the usual determinations of B.O.D., D.O., suspended solids, per cent volatile, and sludge index; together with readings of sewage flow, air used, sludge return, and their computed relationships are recorded and considered in the control of the aeration process. However, the two factors which receive attention on every shift are the suspended solids in the aeration tanks and the D.O. at the effluent end of the aeration tanks.

Samples of mixed liquor are taken at 4-hr intervals and composited for a suspended solids determination on every 8-hr shift. The suspended solids carried in the aeration tanks gives a sludge age (Gould) of about 4 to 6 days, which gives a high degree of treatment. However, the factor of sludge age is not considered in the day to day plant control because it is less sensitive than the suspended solids in the aeration tanks.

Dissolved oxygen determinations are made at 4-hr intervals of samples taken at the effluent end of the aeration tanks. It has been found desirable to maintain a minimum of about 2 ppm D.O. at the effluent end of the aeration tanks in order to be sure of a healthy return sludge.

The ash content of the sewage solids is a subject of frequent discussion because of its effect on the sludge index and on the fertilizer value of dried sludge. The Mohlman⁽⁹⁾ sludge index of settleability is used by the Sanitary District because it seems easier to visualize a figure which is small for a concentrated sludge and large for a bulking sludge.

CONCLUSION

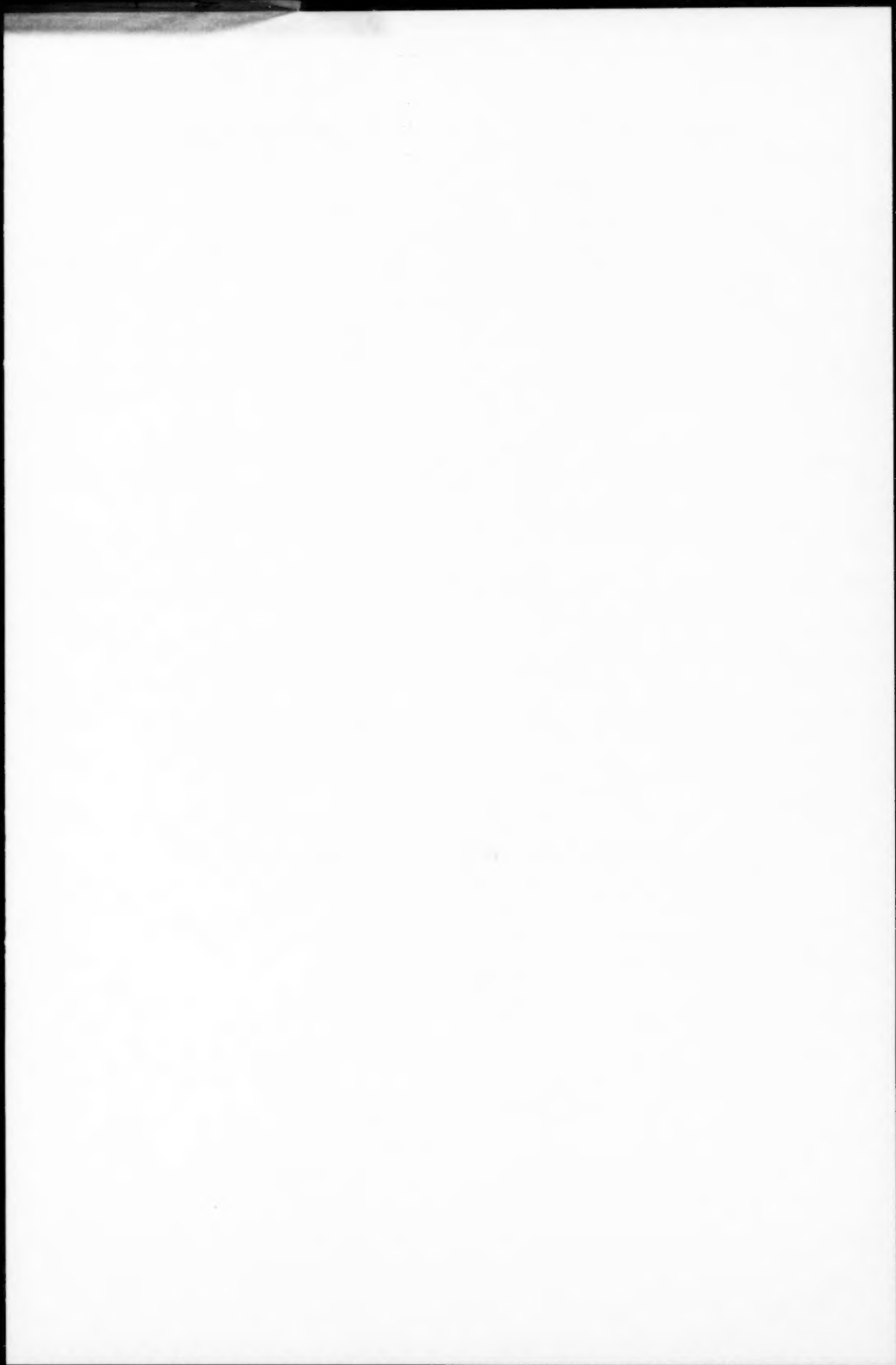
Aeration practice of The Sanitary District of Chicago is what is believed to be best for its requirements, based on present knowledge. Different conditions would, of course, call for modifications. Also, the engineering staff of the District continues to investigate and experiment in quest of improvements in the sewage treatment processes. Although no new sewage treatment plants are contemplated for the Sanitary District within the foreseeable future, it is expected that major additions will be required at the West-Southwest and North Side Works before 1960 in order to handle the increasing population and industrial wastes.

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